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Evaluation of SMED Industrial Method to Increase the Crop Yield of Asparagus Based on Control of pH of Soil and Water in the Agricultural Industry of Mexicali Valley

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ABSTRACT

In this scientific study was made an evaluation to analyze the process to make the setup change in the agricultural industries and improve the times of this change to have a better flow process. This investigation was made in an agricultural industry located in the Mexicali Valley, which is part of the Mexicali city that is located in the northwest of the Mexican Republic and is a border zone between Mexico and Unites States of America (USA) and is a commercial region with the California State of the USA. In this scientific study was evaluated the three principal types of variety of asparagus of agricultural machines as cutter, count and of package of agricultural products as asparagus in an agricultural industry located in the Mexicali Valley, which is necessary change the type of structures of each activity (cutter, count and of package), being the setup change, and make as soon as possible this action. Each structure to each type of asparagus evaluated in this investigation, have size and a time to installed, and to know if was installed the correct structure to each asparagus is necessary control by a computer system to avoid any damage to asparagus products and the agricultural machinery. The method used to evaluate the crop yielding of asparagus and with this the productivity and quality indices, was the Single Minute Exchange of Die (SMED) as an industrial engineering method in the agricultural industry. Also, in this scientific study was made an analysis of the occurrence of corrective, preventive and predictive maintenance and obtain data of the size of asparagus, time of cut and package and the weight and quantity of asparagus cropped, cut off and packaged. This data was obtained by electronic sensors, which are coupled to a computer systems and stored the data obtained to be evaluated with statistical methods with graphs and tables. This scientific study was made in 2022. This investigation was made in the Mexicali Valley, which is located in the northwest of the Mexican Republic.

Keywords: Agricultural industry; SMED method; Asparagus; Computer system.

Introduction

An investigation to evaluate the application of the SMED industrial method to analyze the time of evaluate the setup change of the agricultural machinery was made, where was obtained numerical data of the setup change of the corrective, preventive and predictive maintenance times, where before this scientific study was higher than 30 minutes in the setup change and until two hours in the corrective and preventive maintenance and in some times can't was analyzed the predictive maintenance.

The predictive maintenance was made to determine the cycle time of parts of the agricultural machinery which was necessary replace constantly. After this investigation (at two months of the begin, in March 2022), was decreased the time of setup change until 15 minutes and the time to the corrective and preventive maintenance until 30 minutes, and was made the predictive maintenance forever.

The use of engineering methods in various types of industries, such as the agricultural industry, where there are various types of activities similar to an industrial company, be it aerospace, biomedical, electronics, metalworking, plastics or textiles. This has revolutionized manufacturing processes and increased productivity and quality indices, generated total customer satisfaction and obtained profits, which originates economic bonuses for workers, who every day have a positive attitude with their daily work activities. One of the engineering methods widely used in model or product change processes is SMED, which has the objective of streamlining actions in this

activity that is constantly developing in industries around the world. This action is of great relevance in the flow process of industrial processes, because if it can be elaborated in an optimal way, the productivity goals can be achieved, always taking care of the quality action, to obtain efficient results before the clients and not generate guarantee operations. This should not happen, because it is necessary to apply rework that is not adequate and economic losses are caused by using periods of overtime, in addition to human resources such as workers who must receive compensation for that extra work and finally loss of material, that must be replenished when generating extra purchases and unnecessary expenses.

Location of the Mexicali Valley

This is a rich region about the agricultural activities, where is cropped a lot types of productive food, being principally vegetables as the analysis of the asparagus in this investigation. Is located in the Baja California State, in the northwest of the Mexican Republic as is showed in figure 1 (Moreno et al, 2005), where is observed in dark blue down of the line as the Mexicali Valley in figure1, showed with the red circle (rural area, as the San Quintin Valley), and up of the line is Mexicali city (urban area) (Avendaño et al, 2005).. This is a prosperous region in agricultural activities and is somewhat similar to the San Quintin Valley, located in the south of the state of Baja California, where various types of asparagus are grown in the same way, which is a highly coveted vegetable in our homes.

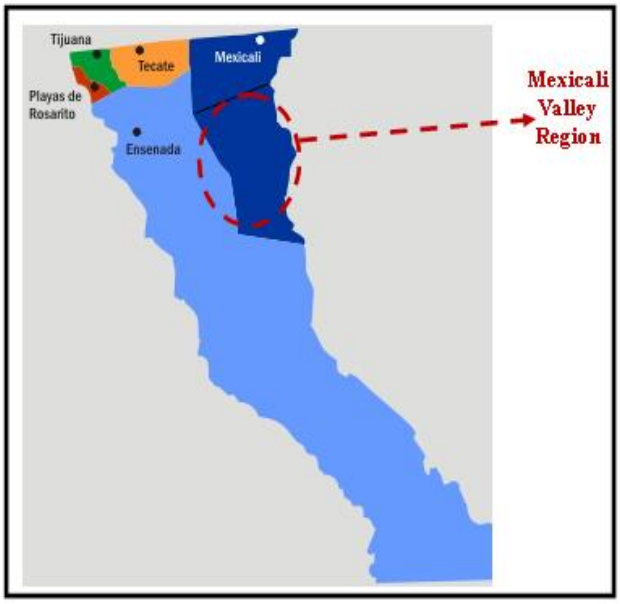

Figure 1. Region of agricultural activities in the Mexicali Valley

SOURCE: Analysis of research literature

Agricultural industry

It is a very important industry worldwide, because based on it, food is developed that is sent to distribution centers to be consumed by the population. Currently, there are various types of agricultural industries, which is depending on the demand that is available worldwide, where sometimes it is not enough to cover the required demand. This is why, sometimes, artificial products are developed or, in the most extreme case, food products called organic,

which are grown in greenhouses as closed places, causing a higher cost of food products, and sometimes causing chaos in the economy of families in every region of the world. Since ancient times, agriculture has been an activity on which it has depended to a large extent because it is relevant for the cultivation and generation of food products, where it was considered a miraculous action for the distribution of food in homes. Previously, fertilizers and pesticides were not used in a drastic way, because the issue of water and soil contamination was not considered, where the cultivation process was elaborated. At present, there are various techniques that can generate crops with higher yields and with this it is necessary to have processes of collection, cutting, separation of products in a consumable or non-consumable state, counting and packaging. For this, investigations have been made to apply industrial engineering methods and require researchers, specialized personnel and productive operators of this subject, who every day apply industrial engineering methods, such as the one used in this scientific study. In this investigation was applied the SMED method.

Variety of asparagus

In the world are a diversity of variety of type of asparagus, which depends of their time of crop, nutrimental properties and size; where are expressed in table 1.

Table 1. Characteristics of variety of asparagus (2022).

Characteristics **Types of asparagus**	**Crop yielding**	**Properties**	**Size**
Apollo Asparagus	Produces a large crop and flowers earlier than many other types of asparagus.	Smooth in appearance and with nice, uniform stems, this type of asparagus is dark green in color and does best in warm or cool climates. Highly resistant to rust and fusarium, Apollo asparagus is ideal for a wide variety of purposes, including freezing, fresh service, and processing.	Its stems are medium to large in diameter and have purple tints at the tips.
Atlas Asparagus	Is resistant to most diseases that affect asparagus plants and does very well in hot climates. It also grows in most climates from 45° to 85° Fahrenheit and can even	It also produces a large crop and is very hardy. It has dark green shoots with some purple on the bud scales and has an especially high tolerance to Fusarium.	It can grow in both hot and cold climates, as long as it is exposed to a minimum of six hours of sunlight per day, and is drought tolerant. The plant can grow up to 1.5

	tolerate frost.		meters tall, while the asparagus itself can grow to around 25 centimeters.
Jersey Series Asparagus	Jersey series asparagus are a hybrid variety of all-male plants and include Jersey Giant, Jersey Knight, and Jersey Supreme. The Jersey Supreme, a fairly new variety, is also disease resistant and can be harvested a little earlier than the Knight or Giant. It is also a good choice if your soil is sandy. Jersey Supreme is more uniform than other asparagus hybrids and grows well in soils that have at least some sands. It is resistant to rust and Fusarium wilt and does best in growing zones 3-8.	Their stems are very thick and they are a perennial plant, so you will be able to enjoy them for many years. They tend to mature in late spring in most climates and do best if you live in zones 4-6. Jersey Knight is resistant to many diseases, including rust, crown rot, and fusarium wilt, among others. It is also a very resistant type of stud. Best grown in zones 3-10, this type of asparagus does well even in cool climates and is high in vitamins A, B6 and C.	The Jersey Giant is hardy and performs well in most climates, including cold ones. It usually grows between 17 and 19 centimeters long and is very meaty and tasty. Also, it tends to get bigger crops the older it is; in the fourth season, you should see a very large and robust crop.
Mary Washington Asparagus	For over a hundred years, the Mary Washington type of stud has been very popular in Europe and the United States.	They taste delicious and their shoots are deep green in color with light purple tips. It is a traditional form of asparagus that grows long and even.	Mary Washington Asparagus is a heirloom variety that is a perennial plant and does best in growing zones 3-8. Its foliage is also quite attractive and is a feathery green color. The asparagus reaches approximately 20 centimeters, while the plant can grow up to 15

			centimeters in height. They also prefer full or partial sun.
D'Argenteuil Early Cooked Asparagus	This type of asparagus is especially popular in Europe, where it originates from.	It is light green in color with pink tips and is a heirloom variety with a very sweet flavor. Asparagus's name means "early" in part, so if you don't have a lot of patience, it's a good option, since you won't have to wait long to harvest this type of asparagus in your orchard or garden.	It became popular in France and is whitish green in color with hints of light pink throughout. It prefers the sun and the plant can reach a meter in height. It also does best in growing zones 5-8. Precoce D'Argenteuil asparagus is tender and very tasty. Begins to thrive in its second year after planting.
Purple Passion Asparagus	Made up of male and female plants, Pasion Morada asparagus takes on a lighter color when cooked. It has an excellent flavor and is best grown in zones 3-8.	Additionally, Purple Passion asparagus is one of the most tender and flavorful types of asparagus, far more tender than other green varieties, which is one of the reasons why it is great in both salads and cooking.	This type of asparagus, with a very marked flavor and tenderness, is also ideal if you need to freeze it for any reason.
Stud UC 157Asparagus	UC 157 asparagus is a hybrid asparagus that does very well in hot climates. It is pale green in color and highly resistant to various diseases. This type of stud was developed in 1978 and is one of the most popular.	Furthermore, it is both a male and a female plant. Rust and Fusarium tolerant, UC 157 asparagus is uniform in both size and color and is a perfect type of asparagus to grow commercially due to its high yield.	It grows well in all growing areas, with the plant reaching a size of between four and five feet when fully mature, including the vegetable itself, and is often found at farmers, if not the most common markets and other local markets.

Viking KB3	Is a fairly new variety and combines male and female plants. .	It is a robust plant that produces large yields and is a very tasty vegetable that can be harvested early. It can grow in most climates and can be harvested when the stems are pencil thin. The stems grow to about four inches long and are very meaty and flavorful.	It is a very easy type of grass to grow and is also a type of Mary Washington Asparagus.

SOURCE: Information obtained from: https://www.sembrar100.com/esparragos/variedades/

This table shows the diversity of asparagus cropped in the world, where in the Mexicali Valley is cropped the first three types of asparagus of this table as mention now: Apollo Asparagus, Atlas Asparagus and Jersey Series Asparagus. These three types depend of the customer, where to the Apollo Asparagus the customer is in the center of the Mexican Republic, the customer of the Atlas Asparagus is this northwest region where is cropped this type of asparagus and the third type called Jersey Series Asparagus the customer is in the California State of the Unites States, which is the neighbor of our country. Of these three types of asparagus, is necessarily have three types of structures in the agricultural machines as

SMED as industrial engineering method

The SMED method is widely applied in any type of industrial company, because it is part of the model or product change actions, as well as the components, devices and parts of industrial equipment and machinery that make industrial operations. The main objective of this industrial method is to develop the changes of the mentioned actions in a period of time of 10 minutes, where the essential periods of time of the flow processes and the manufacturing of the products are concentrated, as they are in this case, food products such as asparagus. The model or product change actions are represented in a matrix of activities called work instructions, where the steps of how to make the changes quickly and efficiently are illustrated. This matrix is presented in Table 2. In this table, are showed the principal steps of the activities to debit be makes efficiently and fast to saves time and avoid the dead times and delays in the production flow and the delay in the delivery of the food products cropped to the customers in different regions of the world.

Table 2. Analysis of steps required to make of changes of setup efficiently and fat in the agricultural industry evaluated (2022)

Factors **Steps**	**Type of device or component**	**Tools to use in the change**	**Observations**
1. Verify the actual type of	Is necessarily know to	Is necessary to know the	Debit occurs with

model installed in the agricultural equipment of machinery	determine the components or devices to change efficiently and fast	tools to use efficiently and fast	no setbacks
2. Verify the type of model to change and install in the agricultural equipment of machinery	Debit know the components and parts before to change to make the change efficiently and fast	Is necessary to know the tools to use efficiently and fast	Debit occurs with no setbacks
3. Specialized personnel will change the model efficiently and fast	Is good determine the method to change the component and device efficiently and fast	Is good use the adequate tool to make the change efficiently and fast	Debit occurs with no setbacks
4. Check the change of the new model	Debit be carefully in the check of the new model to avoid damage the devices and components used in the agricultural equipment and machinery	Debit be carefully in the check of the new model to avoid damage the tools used in the agricultural equipment and machinery	Debit check the new setup of the agricultural equipment and machinery controlled by computer systems
5. Store devices and components, as well as tools in a suitable place			

Computer systems used in the agricultural industry

The computer systems are used a lot operational activities in all industries of the world, where are used as a simple and complex computer systems, being a relevant action in the manufacturing process. The majorly of the computer systems have the objective of actions of control, which are coupled with electronic devices of diverse actions and have options of store and evaluate the numerical data obtained of the operational activities of each step of the flow process in the manufacturing areas. This is very important, where one of the software to associate the industrial operations with the electrical signals to the convert systems of analog to digital signals is the Platform IO, as a tool of the industry 4.0, which is called the Internet of Things (IOT). The system that generates the association of the industrial operations with the electronic sensors and coupled with the computer system is illustrated in figure 2.

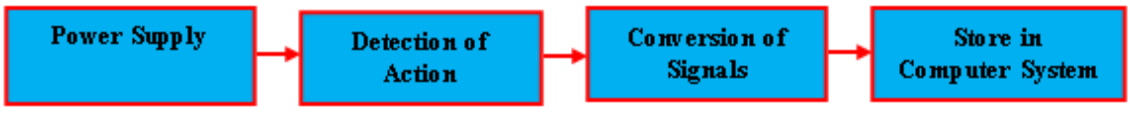

Figure 2. System utilized of association of industrial equipment and machinery with electronic sensors coupled to a computer system – SOURCE: Analysis of research literature

Figure 2 shows the basic four steps that have the relation of the industrial equipment and machinery with the computer systems, which are explained now:

(a) Power supply - was utilized to supply the electrical current to the complete system.

(b) Detection of action - was used to detect some anomalies as different characteristics compared to the specific and original characteristics.

(c) Conversion of signals - was utilized to convert electrical signals as analog signals of electronic sensors associated with the industrial equipment and machinery, to digital signals to be store as bite as numerical data in the computer system.

(d) Store in a Computer System - was used to receive the digital signal of the electronic sensors as a digital signal converted, and stored as a numerical data to be analyzed with statistical methods.

Types of maintenance to agricultural machinery

In each industry exists the maintenance processes, which are elaborated in some periods of the industrial operations, being the most common application the corrective maintenance because occurs when any industrial equipment and machinery is broken of some part of all parts of these industrial systems used in the manufacturing process. Also, is presented the preventive maintenance, which occurs when is necessary prevent some bad actions or to care some parts of the industrial equipment and machinery. And the last type of maintenance is the predictive to prevent any anomalies in some or all parts of the industrial equipment and machinery, where are utilized some statistical methods to predict the lifetime of the some and all parts of these industrial systems.

These types of maintenance support to the industrial operations to have an efficient flow process, where is evaluated the operative yielding of the industrial equipment and machinery to reach the estimated productivity and quality indices, and with this action obtain the most economic gains in each industry of the world. For this action, debit have specialized persons in the manufacturing areas to the three types of the maintenance, especially with the predictive maintenance, which some specialized workers can predict the lifetime of partial or full activities of the industrial equipments and machinery and can detect when will be generate failures or errors these industrial systems. This is very important to determine when can obtain the maximum operative yielding of these industrial systems and can obtain the maximum productivity and quality levels, to can works with fluid industrial processes and reach the goals and have the fabricate products in this case as in this investigation, the crop food products as asparagus evaluated.

Methodology

This investigation was made to evaluate the use of computer systems in an agricultural industry located in the Mexicali Valley, where was made some type of analysis and evaluating the behavior of some parameters involved in this scientific study. The steps of this investigation are expressed now:

(a) Evaluation of the crop yielding of asparagus - was made to determine the crop yielding in base of the setup change of the three types of asparagus.

(b) Analysis of electronic sensors used in the agricultural activities of the industry evaluated - was utilized to evaluate the operation yielding of the industrial equipment and machinery, in base of the application of the three types of maintenance in this agricultural industry evaluated.

(c) Evaluation of the use of computer systems coupled to the electronic sensors - was used to determine by the Spearman analysis if existed a relation of the operative yielding of the industrial equipment and machinery with the productivity and quality indices and the associate with the computer systems that control the electronic sensors coupled to these industrial systems.

Results

This scientific study is relevant because was determined the application of the adequate setup change of models represented in the actions as collection, cutting, separation of products in a consumable or non-consumable state, counting and packaging processes. In the next sections are explained better about this scientific study.

Analysis of setup change

This step of the investigation was made to determine the importance of the setup change in the process of the agricultural industry where was made this scientific study, obtaining relevant numerical data, and evaluate the behavior of the setup change with specialized people, and illustrating in tables 3, 4 and 5; the difference between the activities of the setup change in the agricultural equipment and machinery, respect to compare the time of production, time of setup and dead time before make the investigation and observing the improved situation after of the investigation.

Table 3. Analysis of time of production, setup and dead time of the crop of Apollo Asparagus in the agricultural industry evaluated (2022)

Time Evaluation	Time of Production, min		Time of Setup, min		Dead Time, min		Observations
Month	**BI**	**AI**	**BI**	**AI**	**BI**	**AI**	
January	287	426	117	38	109	52	Improved
February	296	435	123	36	102	47	Improved
March	278	420	129	30	99	38	Improved
April	286	423	115	39	96	33	Improved
May	289	421	110	43	110	30	Improved
June	290	417	107	36	117	40	Improved
July	298	434	124	37	114	43	Improved
August	295	427	117	32	106	48	Improved

September	301	423	127	29	118	45	Improved
October	287	419	130	35	103	41	Improved
November	276	430	113	33	99	38	Improved
December	279	427	118	40	111	35	Improved

BI. Before the investigation, AI. After the investigation

Table 4. Analysis of time of production, setup and dead time of the crop of Atlas Asparagus in the agricultural industry evaluated (2022)

Time Evaluation	**Time of Production, min**		**Time of Setup, min**		**Dead Time, min**		**Observations**
Month	**BI**	**AI**	**BI**	**AI**	**Bi**	**AI**	
January	245	389	145	44	123	66	Improved
February	238	402	139	47	128	64	Improved
March	240	390	141	50	120	58	Improved
April	246	397	136	48	117	54	Improved
May	251	403	140	45	114	50	Improved
June	230	387	147	37	129	57	Improved
July	223	390	129	45	134	53	Improved
August	216	405	137	44	130	61	Improved
September	228	412	141	47	116	63	Improved
October	236	378	132	49	129	56	Improved
November	230	386	138	52	115	58	Improved
December	240	396	142	40	118	57	Improved

BI. Before the investigation, AI. After the investigation

In the tables 3, 4 and 5; are presented the analysis of the periods of time mentioned to the three variety of asparagus, observing the different times as average of five agricultural machines as cutter, counter, package, inspection of weight and size machines. With use of the SMED method was reduced the times of the period of times evaluated and increased the productivity and quality indices, which were relevant in the generation of the economic gains, where was concerned it important aspect before the investigation to managers. This innovation process in the agricultural industry evaluated, which was applied for a long times in other industries as aerospace, biomedical, electronic, metallic, plastics and textile; supports greatly to improve the floe process and with this the productivity and quality levels.

Table 5. Analysis of time of production, setup and dead time of the crop of Jersey Series Asparagus in the agricultural industry evaluated (2022)

Time Evaluation	Time of Production, min		Time of Setup, min		Dead Time, min		Observations
Month	**BI**	**AI**	**BI**	**AI**	**BI**	**AI**	
January	241	367	159	54	134	77	Improved
February	230	370	163	62	139	80	Improved
March	249	373	154	60	130	75	Improved
April	254	365	150	59	137	81	Improved
May	257	359	148	55	143	73	Improved
June	250	360	145	57	147	76	Improved
July	259	353	158	57	144	78	Improved
August	256	357	167	53	142	83	Improved
September	261	352	163	52	140	81	Improved
October	251	348	160	50	150	84	Improved
November	248	346	156	51	151	79	Improved
December	249	358	152	49	148	74	Improved

BI. Before the investigation, AI. After the investigation

Evaluation of types of maintenance of the agricultural industry

The evaluation of the three types of maintenance in this agricultural industry where was made the scientific study, was relevant, because with the SMED industrial method, improved the form to the crop process and increase the crop yielding. In table 6, is showed the analysis of the three types of maintenance, observing the reduce of the three types after of this investigation.

Table 6. Evaluation of the three types of maintenance in the agricultural industry evaluated (2022)

Time Evaluation	Corrective Maintenance, min		Preventive Maintenance, min		Predictive Maintenance, min		Observations
Month	**BI**	**AI**	**BI**	**AI**	**BI**	**AI**	
January	123	48	137	76	149	32	Improved
February	132	44	144	77	154	28	Improved

March	120	46	139	72	152	33	Improved
April	116	40	140	70	168	25	Improved
May	119	43	142	74	179	29	Improved
June	114	48	136	80	170	34	Improved
July	126	39	138	75	166	31	Improved
August	120	37	130	71	160	30	Improved
September	112	45	133	69	170	37	Improved
October	130	42	141	65	172	35	Improved
November	129	41	135	79	175	38	Improved
December	127	40	145	82	177	39	Improved

BI. Before the investigation, AI. After the investigation

Computer activities in the agricultural industry

In this section was made a Spearmen analysis to determine the grade of relation of the use of the electronic sensors associated with the industrial equipment and machinery with the couple computer systems, obtaining relevant information with the next evaluation expressed in tables 7 and 8, which illustrated the evaluation of the parameters mentioned.

Table 7. Analysis of operation yielding of ten industrial machines relating the OYBITIOT and OYAITIOT in the manufacturing process of the automotive industry evaluated (2022)

Factors / **Industrial Machine**	**OYBUCS, %**	**Hierarchy indices**	**OYAAUCS, %**	**Hierarchy indices**	**Dif=Abs (OYBUCS – OYAUCS)**	**Dif = Abs [(OYBUCS – OYAUCS)^2]**
1	46	9	65	10	19	361
2	53	2	71	4	18	324
3	49	6	68	7	19	361
4	50	5	70	5	20	400
5	51	4	74	1	23	529
6	54	1	72	3	18	324
7	52	3	73	2	21	441
8	45	10	69	6	24	576
9	47	8	67	8	20	400
10	48	7	66	9	18	324
Total	532	55	695	55	202	4040

OYBUCS - Operative Yielding Before Use the Computer Systems, OYAUCS - Operative Yielding After Use the Computer Systems.

Table 8. Spearmen analysis of the operation yielding of ten industrial machines in the manufacturing process of the automotive industry evaluated (2022)

Factors Industrial Machine	Hierarchy indices, OYBUCS	Hierarchy indices OYAUCS	Dif=Abs (OYBUCS – OYAUCS)	Dif=Abs (Dif = Abs [(OYBUCS – OYAUCS)^2])
1	9	10	1	1
2	2	4	2	4
3	6	7	1	1
4	5	5	0	0
5	4	1	3	9
6	1	3	2	4
7	3	2	1	1
8	10	6	4	16
9	8	8	0	0
10	7	9	2	4
Total	55	55	14	32

OYBUCS - Operative Yielding Before Use the Computer Systems, OYAUCS - Operative Yielding After Use the Computer Systems.

$$r = \{1- [(6*32) / (10*(10^2-1)]\} = [1-(192/990)] = 1-0.19 = 0.81$$

This indicates that the correlation of the use of computer systems in this agricultural industry valuated in this investigation was good correlation, representing that is very important use this relevant tool, as the utilized in this scientific study.

Conclusions

The use of the SMED as industrial method, but not was applied previously in the agricultural industry, but applied in other type of industries, as mentioned above. This scientific study improved the productivity and quality levels and with this the economic gains of the industry evaluated. This investigation got relevant results about the cultivation and crop processes of asparagus in the Mexicali city, which is a region located in the northwest of the Mexican Republic and were participate specialists of this interesting thematic. One of the important aspects to be able to grow a coveted vegetable, which is asparagus; is the preparation of the soil, in addition to controlling the pH of the soil where it is grown and the water that is used, always considering the parameters of temperature and relative atmospheric humidity, which can influence the temperature of the soil where this vegetable is grown and the water used in the process of growing and harvesting asparagus. It is necessary to make trench furrows with a width of 30 centimeters, to place a layer called humus, in addition to compost, manure and nutrients, such as those mentioned above in this scientific study process.

Declarations

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This research did not receive any specific grant from funding agencies in the public, or not-for-profit sectors.

Competing Interests

The authors declare no competing financial, professional and personal interests.

Consent for publication

We declare that we consented for the publication of this research work.

Availability of data and material

Authors are willing to share data and material according to the relevant needs.

References

Argüelles López C. (2014). Reducción de tiempos de preparación, mediante SMED. en una empresa metal-mecánica, México, Pages 89.

Berger, A., Restaino, E; Otaño, C., Sawchik, J. (2019). Agricultura de precisión: qué es y cuánto se usa en Uruguay? (en línea). Revista INIA, (59): 41-45.

Campari, J. (2021). Los sistemas alimentarios y la propuesta de vías de acción y objetivos de investigación. In Diálogo Virtual Independiente para la Cumbre de los Sistemas Alimentarios (FSS) 2021: ciencia, tecnología e innovación para transformar los sistemas alimentarios de América Latina. s.l., Cumbre de los Sistemas Alimentarios.

Campbell, BM., Vermeulen, SJ., Aggarwal, PK., Corner-Dolloff, C., Girvetz, E., Loboguerrero, AM., Ramirez-Villegas, J., Rosenstock, T., Sebastian, L., Thornton, PK., Wollenberg, E. (2016). Reducing risks to food security from climate change. Global Food Security, 11: 34-43.

Channarayappa, C., Biradar, DP. (2018). Soil basics, management and rhizosphere engineering for sustainable agriculture. Boca Raton, Estados Unidos de América, CRC Press, Pages 829.

Echeverría, R. (2021). Innovación para sistemas agroalimentarios sostenibles, saludables e inclusivos y sociedades rurales de América Latina y el Caribe: marco de acción 2021-2025. Santiago, Chile, FAO, Pages 38.

Fabregas, R., Kremer, M., Schilbach, F. (2019). Realizing the potential of digital development: the case of agricultural advice. Science, 366(6471).

Motyl, B., Baronio, G., Uberti, S., Speranza, D., Filippi, S. (2017). How will change the future engineers' skills in the industry 4.0 framework? A questionnaire surveys. Procedia Manufacturing, 11: 1501-1509.

Mourtzis, D., Vlachou, E., Dimitrakopoulos, G., Zogopoulos, V. (2018). Cyber-physical systems and education 4.0 -the teaching factory 4.0 concept. Procedia Manufacturing, 23: 129-134.

Mourtzis, D. (2018). Development of skills and competences in manufacturing towards education 4.0: a teaching factory approach. En J. Ni, V. D. Majstorovic y D. Djurdjanovic (Eds.), AMP 2018, Actas de 3rd International Conference on the Industry 4.0 Model for Advanced Manufacturing, Springer, Pages 194-21.

Onar, S. C., Ustundag, A., Kadaifci, C. K., Oztaysi, B. (2018). The changing role of engineering education in industry 4.0 era. En A. Ustundag y E. Cevikcan (Eds.*)*. Industry 4.0: managing the digital transformation, Springer, Pages 137-151.

Prifti, L., Knigge, M., Kienegger, H., Krcmar, H. (2017). A competency model for Industrie 4.0 employees. En J. M. Leimeister y W. Brenner (Eds.), Actas 13th International Conference on Wirtschaftsinformatikk, Gallen, Switzerland, Pages 46-60.

Sackey, S. M. y Bester, A. (2016). Industrial engineering curriculum in Industry 4.0 in a South African context. South African Journal of Industrial Engineering, 27(4): 101-114.

Sánchez, F., Soler, A., Martín, C., López, D., Ageno, A., Cabré, J., García, J., Aranda, J. y Gibert, K. (2018). Competency maps: an effective model to integrate professional competencies across a STEM curriculum. Journal of Science Education and Technology, 27(5): 448-468.

Sifuentes Samatelo (2017). Mejora de la productividad en una empresa de empaques flexibles aplicando la herramienta single minute exchange of die (SMED), Lima.